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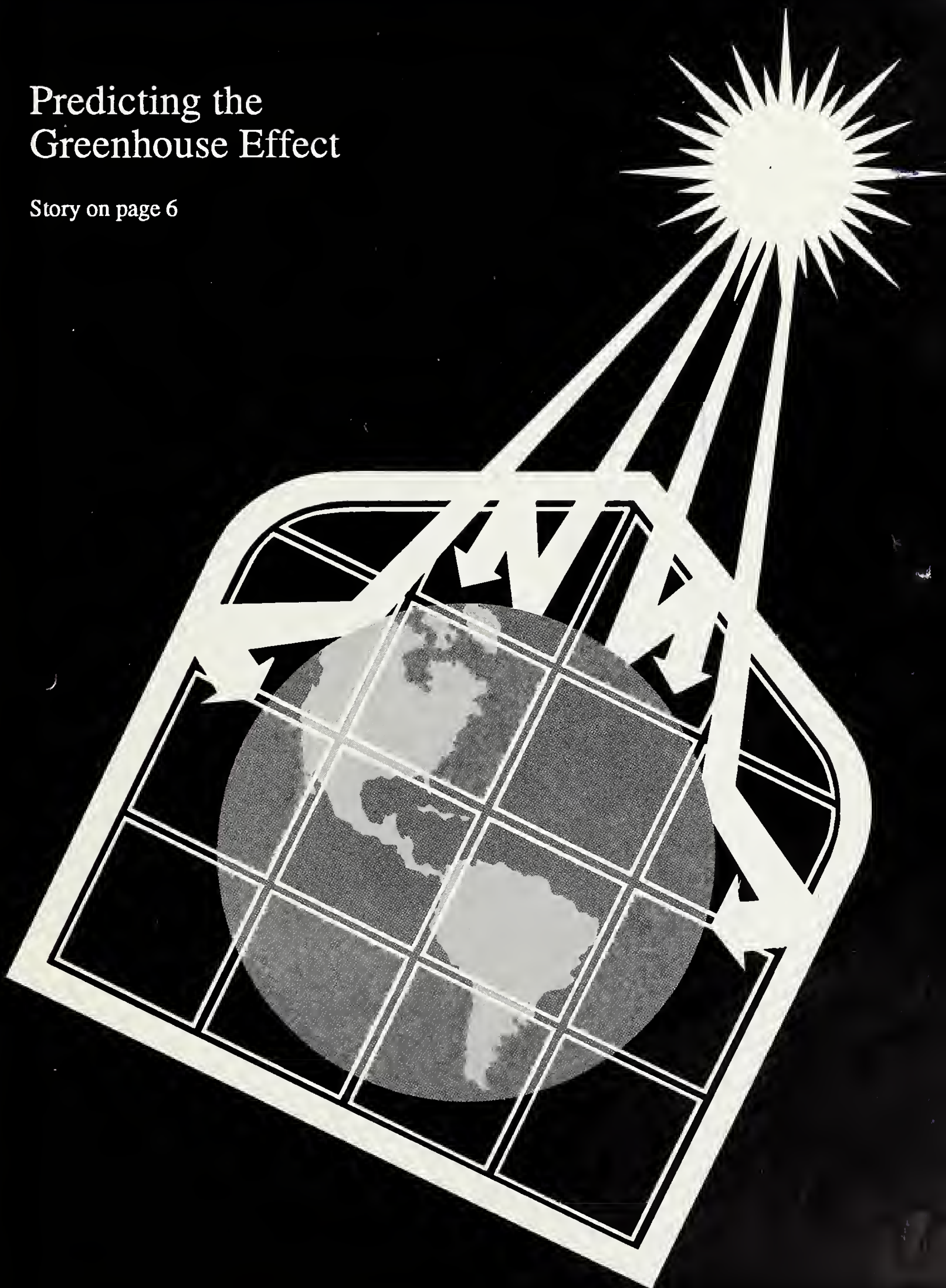

Predicting the Greenhouse Effect

Story on page 6

An Imperative for Computer Modeling

Several computer programs that simulate what may happen as carbon dioxide (CO_2) builds up in the atmosphere are being developed by scientists around the world. Generally, these models predict that there will be a CO_2-induced warming trend, a sort of greenhouse effect from trapped solar heat. The models deal primarily with the temperature change likely to take place and its ramifications—coastal flooding, shifting of the temperate zones northward, and more. But a warming trend is only part of the picture. The effects of additional CO_2 on plant life also command our attention.

Will higher levels of atmospheric CO_2 lead to increased photosynthesis among plants? If so, how will that affect crop production? Will weeds be more or less of a problem?

These questions have been addressed to a limited extent in field and laboratory experiments. But to see what the answers might be in the year 2050, data from the real life tests are being used in computer models that mathematically simulate plant growth at higher concentrations of CO_2.

Unfortunately, the construction of computer models for crop production has been a largely inefficient endeavor. The work is mostly done by small scientific teams that, although interdisciplinary, are limited in the knowledge they can share. Each modeling team often winds up writing its own computer programs for photosynthesis, transpiration, etc., regardless of whether models for other plants have perfectly good components for the same functions or processes. Furthermore, models are often so idiosyncratic that outsiders cannot understand them and contribute their own expertise.

One step to overcoming these problems would be an agreement among scientists to adopt a generic modular structure for plant models. The structure would be applicable to all species and accommodate all plant processes. A generic model structure would consist of many modules, each with a clearly defined function. Some modules, such as those dealing with soil physics, would be the same for all plant models. Other modules would differ among species because of the different processes involved.

Photosynthesis, for example, would be the subject of one module because all green plants photosynthesize. But there would be at least three versions of that module corresponding to the three major photosynthetic pathways. Within each module, scientists could formulate their own hypotheses as to what is happening in the photosynthetic pathway being represented. Modules could be exchanged as appropriate—much as a modular phone can be plugged into the telephone system.

Most existing plant models are organized into subroutines or modules representing basic biological processes. However, the contents and structures of the models have been developed solely for the convenience of the modelers with little thought given to making the model accessible to others. A leaf temperature algorithm might be added to a subroutine for soybean water use, for example, merely because the plant's transpiration rates (and associated heat losses) are also calculated there. The water-use module is now encumbered by extraneous programming that makes it more idiosyncratic and difficult to understand.

Nobody can impose a generic modular structure on scientists, and it will have to evolve through discussion. However, we propose the following criteria for the ideal structure:

- the modules should separate easily along disciplinary lines;
- they should have a minimum number of input and output variables;
- these input and output variables should, as far as possible, be measurable and quantifiable characteristics of the system;
- modifying one module should not necessitate changing any other module;
- the structure should be suitable for modeling all plant species;
- it should be possible to subdivide the modules and introduce whatever detail is necessary; and
- each module should use as input either measured values or the relevant output from any other module.

In addition to needing broad agreement on a structure, we need a way to make the computer code for modules readily available to all scientists. Since scientific journals tend to carry only a few lines of code, the ARS Model and Database Coordination Laboratory is exploring the possibilities of electronically publishing the codes for whole models and modules.

Agreement on a generic modular structure for plant growth simulators, coupled with the development of an effective system for publishing the modules, will encourage more researchers to participate in agricultural model development and evaluation. This, in turn, will facilitate and hasten the development of computer models that simulate the response of crops to increased CO_2 concentration and to the climate changes induced by the greenhouse effect.

Basil Acock
ARS Systems Research Laboratory,
Beltsville, Maryland

Agricultural Research

Cover: Rebounding from the Earth's surface, heat from the sun is trapped within "Greenhouse Earth." Cover by Roy Nash.


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DEPARTMENTS

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Anticaking Agent May Detox Chicken Feed

Chickens that eat feed contaminated with as little as 10 parts per million of aflatoxin may die. Even much smaller amounts may cause them to put on less meat, produce fewer eggs, and have lower resistance to disease.

So scientists have long searched for a way to combat this poisonous substance, produced by a mold that sometimes infects corn, cottonseed, peanuts, and other grains [Aflatoxin—No One Solution, *Agricultural Research,* November/December 1985]. But the "magic bullet" might have been sitting on the feedstore shelf all along, report Agricultural Research Service scientists.

Leon F. Kubena, animal nutritionist and Roger B. Harvey, veterinarian at College Station, Texas, have discovered another use for an aluminosilicate-based compound that has been used commercially to keep feed from caking. They found that it also absorbs aflatoxins in chickens.

Its aflatoxin-absorbing properties were discovered by Timothy D. Phillips of Texas A&M University, College Station, who has worked cooperatively with Kubena and Harvey.

Kubena says one-half to none of the typical disease signs appeared when test chickens ate aflatoxin-contaminated feed treated with the compound. Apparently, the compound "tied up the aflatoxin so that it usually passed harmlessly through the intestinal tract."

Aflatoxins are produced by several molds that grow on grain, most commonly *Aspergillus flavus.* Corn is usually infected in the field, although it can become infected after harvest by contaminated handling equipment. Outbreaks occur mostly in the southeastern United States because the mold flourishes in warm, moist weather. The mold costs the poultry industry up to $100 million annually in bird deaths and reduced production.

Magnified view of a kernel of corn infected with *Aspergillus flavus,* a fungus which produces aflatoxin. (PN-7272)

"The anticaking agent is rated 'generally recognized as safe' by the Food and Drug Administration," he says. "But FDA approval is still needed before it can be used against aflatoxin in poultry feed."—By **Vincent Mazzola**, ARS.

Leon F. Kubena is in USDA-ARS Mycotoxin Research, P.O. Drawer GE, College Station, TX 77841 (409) 260-9249. ♦

Tomatoes Prefer Red Mulch, Potatoes Like It White

Tomato harvests dramatically increase in size and quality when plants are grown over red mulch. But potatoes and green peppers produce better when the mulch is white. Michael J. Kasperbauer, a plant physiologist, and Patrick G. Hunt, a soil scientist with the Agricultural Research Service, are studying plant reactions to the application of plastic or straw mulch, a practice that conserves soil moisture and keeps weeds down. They have found that many plants respond favorably to specific wavelengths of reflected sunlight.

"Plastic is generally available only in black or white, while straw has its own unique hue. But we can color either one to make our own designer mulches," says Hunt. He and Kasperbauer work for ARS in Florence, South Carolina.

Results from the first year of field trials on tomatoes surprised the researchers, who did not expect the red-surfaced mulch to affect yield. "We got 20 percent more number-one-quality tomatoes, the ones which bring the most money," says Hunt.

In 1987, the second year of testing colored mulches, tomato plants grown with red produced 37,057 pounds of fruit per acre compared to 32,921 for those mulched with black—not quite the 20-percent improvement of the first year, but still a significant difference in yield, just for changing the surface color of the plastic. The team is applying for a USDA-ARS patent on colored mulches.

"We were not surprised that exposure to reflected red light changed the shape of tomato plants," says Hunt, "But the increase in yield was a bonus."

This past summer, the team began checking other crops to find their favorite colors. They tested, for instance, the effect on potato yield of mulches painted white, blue, yellow, and red, as well as no mulch at all. The plants distinctly preferred white mulch, which increased potato yields 25 percent, compared with red, blue, yellow, and no mulch. "While red- and blue-mulched plots produced the same total weight of potatoes, plots with red mulch had more of the highest quality potatoes," says Hunt.

Like potatoes, bell pepper plants also produced higher yields over white mulch—8,365 pounds an acre compared to 6,990 pounds with traditional black plastic.

The discovery is good news for small growers. The concept of colored mulch is every bit as adaptable to the backyard garden as to large-scale production of high-value crops.—By **Kim Kaplan**, ARS.

Michael J. Kasperbauer and Patrick G. Hunt are inUSDA-ARS Soil and Water Conservation Research, P.O. Box 3039, Florence, SC 29502 (803) 669-5203. ♦

A tiny mite, *Amblyseius limonicus*, smaller than a grain of pepper, on a mirror plant leaf. (PN-7265)

Tiny Homes in Plant Leaves Shelter Beneficial Mites

Leaves of coffee, dogwood, camphor, and many other trees have tiny shelters that may provide haven for beneficial mites, according to Agricultural Research Service scientists. They suspect these shelters serve as built-in defense mechanisms that have evolved with the plants.

Entomologist Robert W. Pemberton says the shelters, known as leaf domatia, have been largely overlooked by science. "Our evidence is preliminary, but it strongly suggests that mites living in the shelters protect the plants against harmful insects and fungi," says Pemberton, who is based in Bozeman, Montana.

Pemberton and ARS colleague Charles E. Turner, a botanist in Albany, California, found domatia-dwelling mites in 31 out of the 32 species of trees and shrubs they inspected. Among them were holly, ash, oak, bay, viburnum, custard apple, and gardenia. "About 75 percent of these mite species are probably beneficial," says Turner.

These mites are usually translucent, white or cream, eight-legged creatures, smaller than the period that ends this sentence.

Phytoseiid mites—the ones Pemberton and Turner found most often on leaves they inspected—are fast-moving predators best known for their ability to capture and devour spider mites, notorious plant damagers that feed on leaves. Another group, tydeid mites, that Pemberton and Turner often found typically feeds on spores and filaments of disease-causing fungi or on harmful mites, insects, or their eggs.

The scientists estimate that more than 1,000 plant species, including varieties of such economically important ones as walnut, cherry, grape, linden, elm, oak, and rubber, have domatia.

According to the researchers, most domatia occur on the underside of leaves of woody plants, at the junction of the main and lateral veins. They vary in shape, ranging from pits or pockets to tufts of short hairs, miniature thickets that mites hide in.

A Swedish scientist coined the word domatia, meaning "little home," about 100 years ago. Since then, little attention was paid to mites and leaf domatia, until 1983, when Pemberton and Turner first began to study how plants and mites interact.

The researchers think that this interaction is what is known as a facultative mutualism. This means that neither the presence of mites nor domatia-bearing plants is necessary for each other's survival, yet each will benefit significantly from the other.—By **Marcia Wood**, ARS.

Robert W. Pemberton is in USDA-ARS Rangeland Insect Research, Montana State University, South 11th Ave., Bozeman, MT 59717 (406) 994-4890. Charles E. Turner is in USDA-ARS Plant Protection Research, Western Regional Research Center, 800 Buchanan St., Albany, CA 94710 (415) 559-5975. ♦

Dwarf Corn Shades Weeds

Corn farmers may save herbicide and conserve soil by adopting two techniques developed by an Agricultural Research Service scientist.

Double the number of plants per acre by narrowing row spacing and planting a shorter (dwarf) corn hybrid, suggests Frank Forcella, an agronomist with ARS in Morris, Minnesota.

"Just like an umbrella, the plant leaves form a canopy of shade over weeds. We're robbing weeds of sunlight by getting a canopy in 4 weeks rather than 8 weeks with tall corn. Weeds need a lot of sunlight, especially during the first 6 weeks of growth, when they can take over the corn," says Forcella.

He and his colleagues at the North Central Soil Conservation Research Laboratory, planted dwarf corn in 15-inch rows instead of 30-inch rows. This doubled the number of plants per acre to 50,000. Because of the quick growth of the dwarf corn's leaf canopy, the research team got away with applying only one-third of the amount of herbicide recommended to control foxtail.

"On the average, herbicides cost $21 an acre, so we saved $14 an acre by using two-thirds less. On 100 acres of corn, the savings would be $1,400," says Forcella.

Forcella thinks that farmers who use the dwarf corn and narrower rows could also prevent erosion. "The field looks like a tall green lawn. The thicker, denser crop protects the soil from heavy rainfall, reducing soil erosion."

Although dwarf corn typically does not yield as much as tall corn on a per acre basis, it is used because it matures in only 75 days. The dwarf variety is more commonly grown in the northern part of the Corn Belt—Minnesota, Wisconsin, and Michigan. Only one variety is available commercially, but others may be developed as farmers become aware of the benefits of using dwarf corn.—By **Linda Cooke**, ARS.

Frank Forcella is in USDA-ARS Soil Management Research, North Central Soil Conservation Research Laboratory, Morris, MI 56267 (612) 589-3411. ♦

Agriculture and the Greenhouse Effect

Like the glass in a greenhouse, atmospheric carbon dioxide (CO_2) tends to let the sun's rays through and keep their heat from leaving. In recent years, the term "greenhouse effect" has worked its way into our environmental vocabulary. It refers in both a popular and technical sense to an anticipated warming of the global climate due primarily to an industrialized world burning more and more fossil fuels and spewing more and more CO_2 into the atmosphere.

CO_2 is a byproduct of fossil fuel consumption; its buildup is a natural consequence of a modern civilization's need for more energy. According to the Department of Energy (which has overall responsibility for federal research on the CO_2 question), the main users of fossil fuel energy are industry, transportation, power production, and agriculture.

"... there is little doubt that wheat, rice, and corn—the three major foods for Earth's population—will benefit from extra CO_2."

W. Doral Kemper, ARS Climate Impact Program, Beltsville, Maryland

JACK DYKINGA

Above: In an open CO_2-enrichment chamber at the ARS Western Cotton Research Laboratory, physicist Sherwood Idso (left)and soil scientist Bruce Kimball examine cotton subjected to a double dose of CO_2. (0985X1005-8)

Right, top: Bruce Kimball checks control valves that are set to a computer-controlled level to provide a consistent CO_2-enriched environment to the test chambers. (88BW0170-7)

Right: At sundown and sunup each day, Sherwood Idso removes tiny leaf samples from agave plants for chemical analysis to determine the amount of CO_2 the plants have accumulated during the night. Agave, a desert plant, is used because it brings CO_2 into its leaves at night and loses less water than other plants. Idso leans over the clear tubes that bring CO_2 into the chamber. (88BW0169-12)

From a scientific point of view, "greenhouse effect" is indeed a good description of the physics behind what some scientists think may already be occurring: a slight increase in average temperatures around the world. The widespread use of the term, however, arises more from an intensifying public and scientific debate on whether a truly significant warming trend is likely—and what it would mean for life on our planet in the future.

This much we know: the amount of CO_2 in our atmosphere has been increasing every year since the industrial revolution began, and the rate of increase has accelerated considerably in the last 30 years. Right now, we're at 345 ppm (parts per million) compared to 315 ppm in 1958.

We also know that, while CO_2 concentrations are greatest over industrialized areas, the gas is slowly but surely being dispersed by air currents circulating throughout the northern and southern hemispheres. In other words, rising levels of atmospheric CO_2 are not just an urban phenomenon like lingering smog.

Here the facts we are sure of end. The warming of the earth, the melting of the polar icecaps, the rising sea levels, and the flooding of inland communities—this is a lot of speculation, educated guesswork, and computer modeling.

What about agricultural production? Many scientists predict that atmospheric levels of CO_2 will nearly double to 650 ppm by the year 2050. If they are correct, what will this mean for agriculture in America and around the world?

"There is one major area of consideration as far as agriculture is concerned," says W. Doral Kemper, head of the ARS Climate Impact Program in Beltsville, Maryland. "That is how a continued buildup of CO_2 could affect crop growth and yield. The question of temperature increases must be ad-

dressed, of course, but the main concern is how doubled CO_2 will affect agriculture."

A French scientist named Nicolas T. de Saussure first demonstrated in 1804 that peas exposed to high concentrations of CO_2 grew better than peas in regular air. Since then, numerous experiments have been performed on other crops showing that they too thrive on a CO_2-enriched environment. Today, many vegetable and flower growers routinely pump extra carbon dioxide into their greenhouses to boost yields.

Kemper believes increased CO_2 will be good for agriculture in America.

"While other groups of scientists are writing disaster scenarios about drought, decreased yields, and rising sea levels," he says, "our data indicate benefits. And there is little doubt that wheat, rice, and corn—the three major foods for Earth's population—will benefit from extra CO_2."

Bruce A. Kimball, a soil scientist with the ARS Water Conservation Laboratory in Phoenix, Arizona, agrees. Kimball has been reviewing research reports from around the world on crop growth and yield in CO_2-enriched environments.

"The evidence clearly points to greater crop productivity in a CO_2-enriched environment," he says, "but not all crops are likely to respond to the same degree."

If atmospheric levels of CO_2 should double, according to Kimball, cotton yields would probably soar about 80 percent. Small grains like wheat and rice would go up by 36 percent. Corn production would increase by maybe 16 percent.

Projections of this kind are based on experimental evidence. For the past 5 years, Kimball and Jack R. Mauney, a plant physiologist at the ARS Western Cotton Research Laboratory in Phoenix, have been growing cotton in open-topped, outdoor chambers containing elevated levels of CO_2.

"In addition to measuring the growth of cotton plants inside the chambers," says Mauney, "we've been looking at such things as their leaf temperature and transpiration rates, indications of a plant's water use efficiency. We found

water use to be about the same even though plant growth was way up.”

Another benefit of the greenhouse effect could be less wind and water erosion. Higher crop yields, suggest the scientists, would lead to more harvest residues like stalks and straw, which help to hold the soil in place.

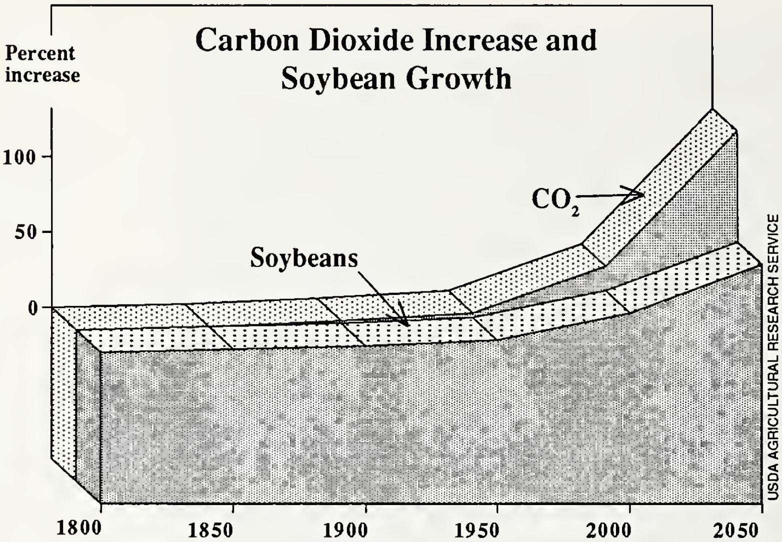
“Of course, more fertilizer might be needed to replenish soil nutrients that have been taken up by the higher yielding plants,” says Mauney. “That’s something else we have to think about. And what about weeds? If crops like the extra CO_2, weeds might react the same way.”

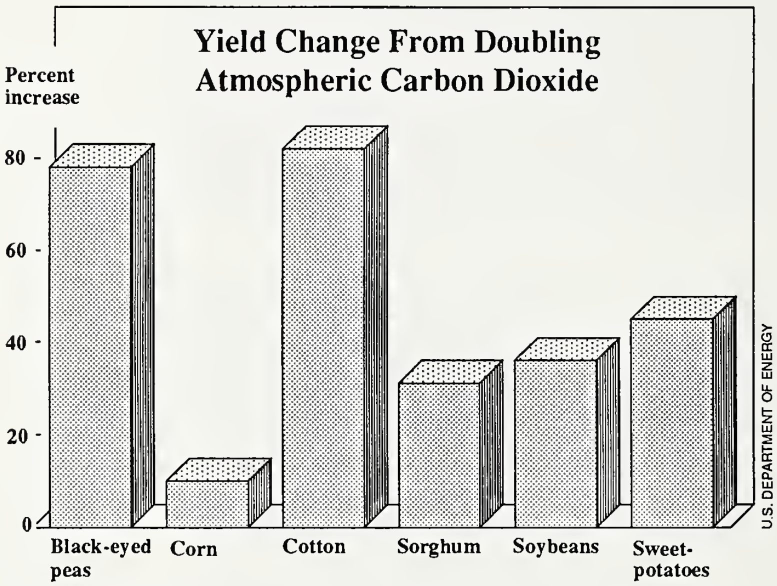
Insects on CO_2-enriched cotton plants are also being monitored.

David H. Akey, an entomologist at the cotton lab, reports that pink bollworms in high-CO_2 chambers grew and developed the same as on regular cotton. Levels of pests such as the sweet-potato whitefly were about the same. However, beet armyworms were reduced in weight, took longer to develop, and survived less.

Increased temperatures, on the other hand, could cause insects to grow faster and reproduce more frequently.

“We’re not as confident in predicting temperature increases or their consequences as we are in dealing with elevated levels of CO_2,” says Kemper. “There’s still a lot of controversy as to how much warmer our climates are likely to become.”





In the top graph, carbon dioxide concentrations rise from 280 ppm in 1800 to 650 ppm in 2050, an increase of 132 percent. Corresponding data based on growth chamber experiments and mathematical models suggest that soybean biomass (total aboveground dry matter) would increase by 57.5 percent, from 5,228 pounds per acre to 8,234 pounds per acre over the same time period. Actual seed yields would increase by only 36 percent. The relationship between atmospheric CO_2 concentrations, biomass, and crop yield is an important consideration in studies of the greenhouse effect. The bottom graph shows the yield increases of several crops in growth chambers with CO_2 levels doubled to 650 ppm.

Not everyone agrees that a warming trend will even occur—at least a lasting one. In Germany, scientists working with computer models recently concluded that a rise in global temperatures will evaporate more ocean water and create enough cloud cover to block some of the incoming sunlight.

“Cloud cover would certainly play an important role,” says Sherwood B. Idso, a physicist at the water conservation lab. “And it’s one thing that hasn’t been accounted for very well in our modeling of the greenhouse effect.”

Idso also has doubts that a warming trend, if there is one, will amount to much. Nevertheless, he and Kimball are considering the possibilities. And they have found that plants grow the most when CO_2 levels and temperature are both raised.

“Using the 6°F rise in worldwide temperatures that many climate modelers see as accompanying an increase in CO_2,” says Idso, “we see worldwide crop yields going up by 56 percent instead of the 30 percent that our earlier calculations indicated.”

In Gainesville, Florida, scientists have studied the growth of soybeans, rice, citrus seedlings, and tomatoes in sunlit, controlled-environment chambers having either low or high concentrations of CO_2.

“One way of testing our computer projections for the future is to look at the past,” says soil scientist L. Hartwell Allen, Jr., who heads up the Gainesville research. Allen grew soybeans and rice at 660 and 990 ppm (double and triple the 1973 level of atmospheric CO_2) and at 280 ppm, which represented conditions before the industrial revolution. Other tests run at 160-220 ppm simulated Ice Age levels. (Bubbles of ancient air trapped in core samples of Greenland and Antarctic ice

JACK DYKINGA

Using a porometer, bioscience technician Stephanie Johnson measures water loss from leaves of a sour orange tree growing in a CO_2-enrichment chamber. (88BW0169-2)

provide scientists with historical data on the atmosphere's composition.) "These crops grew the way our models predicted they would," says Allen. "This confirms our ability to accurately predict crop productivity across a wide range of CO_2 conditions."

For their largest and perhaps most realistic experiments, agency scientists at Phoenix and Gainesville are turning to an 18-acre test site recently established by the U.S. Department of Energy (DOE) near Yazoo City, Mississippi. In a cooperative progam with Brookhaven Laboratory, Tuskegee University, and USDA, an estimated 16 tons of CO_2 per day are transported to the site from the nearby Mississippi Chemical Corporation (which donates the gas) and released through automated, computer-controlled valves onto open test plots about 66 feet in diameter.

Brookhaven National Laboratory, Upton, New York, manages the operation of the system.

"By leaving the plots totally exposed to wind, rain, and other elements," says Roger Dahlman, program manager in DOE's Carbon Dioxide Research Division, "we hope to create conditions for plant research that are natural and as close as possible to the kind expected in the middle of the next century."

Ultimately, the data collected near Yazoo City—as well as the data from growth chamber studies at Phoenix and Gainesville—will be used to test, refine, and validate computer models of crop productivity in a high CO_2-world.

Some of these models are already under construction. And although each of the models will represent a different plant, they will all have one thing in common:

"Everything in the computer modeling of plants starts with carbon fixation," says Basil Acock, a plant physiologist with the ARS Model and Database Coordination Laboratory in Beltsville. "To model a plant's growth and production of food is to model the way it utilizes carbon in the photosynthetic process."

In a high-CO_2 environment, Acock explains, some plants will metabolize the extra carbon more readily than others.

"Our computer modeling work shows how important this can be in predicting future yields," he says.

"Of course, when we're considering a long-term buildup of atmospheric CO_2, an enormous number of interlocking models are needed to examine all the possibilities."

To expedite the development of these models, Acock suggests that scientists agree upon a "generic modular structure" in which all plant models would consist of interchangeable, or modular, components representing fundamental biological processes.

"We're talking about the computer simulation of whole crop ecosystems and their evolution in a changing physical environment," says Acock. "The participation of many scientists representing diverse areas of expertise is essential. They need not work together so long as their separate works can fit together. That's what a generic modular approach is all about." *[Basil Acock discusses the imperative for interchangeable parts to computer models in this month's FORUM, page 2.]*

Can we model the human element? Can we predict how farmers themselves will accommodate the greenhouse effect?

"It shouldn't be much of a problem for U.S. farmers," says Kemper. "They're fairly versatile and have demonstrated an ability to adapt to change. Our plant physiologists and crop breeders will help, if necessary, to select crop varieties tolerant of high temperatures. And the fact that the changes will be so gradual means there is plenty of time for our food production complex to adapt."

The sheer size of America offers additional options, according to Kemper. If national rainfall patterns shift— as some modelers predict—so that less rain falls in the center of the country and more in the coastal states, production of crops requiring large amounts of water can shift to the coastal states as well.

"Similarly, if average temperatures in some states should rise above the optimum for a particular crop," Kemper says, "the primary zone for production of that crop would shift northward. Crops that do better under warmer conditions would take their place."—By **Steve Miller,** ARS. **Dennis Senft,** ARS, contributed to this article.

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It's Code Named CARNA 5

It first surfaced in France in 1972, causing devastating losses to the tomato crop, but nobody knew what they were dealing with. They thought a well-known virus had simply run amok.

Scientists here, concerned that the same thing could hit in the United States, started looking into what made the French tomato plants turn brown and die. By 1977, ARS researchers had identified the lethal agent as a viral satellite, the third known to exist and the first known to harm crops.

The agent was given the code name CARNA 5 for cucumber mosaic virus associated RNA number 5. [The genes of most plant viruses are RNA (ribonucleic acid), not DNA (deoxyribonucleic acid), as they are in higher organisms.]

A viral satellite is an incredibly minute piece of genetic material that hides inside a virus and sponges off it for its very survival. At first, scientists believed the satellite to be an inactive chunk of viral genes. But it turned out to be an infectious particle that multiplied only when its parent virus—the cucumber mosaic virus—replicated inside a plant cell.

The scientists soon realized that CARNA 5 led a double life. In tomato plants, it instigates a severe disease like that in the French case, but in peppers and several other plants, it lies low and even keeps its virus host in check, says one of its discoverers, ARS chemist Jacobus M. Kaper.

According to co-discoverer Howard E. Waterworth, now ARS' national program leader for plant health, cucumber mosaic virus is capable of infecting almost every crop in the United States but presently causes noticeable losses only in peppers and some melons in the southern states. Viruses can't be controlled with chemicals, and we do not have varieties that are resistant to many viruses. However, if scientists could isolate the peaceful types of CARNA 5, it may be possible to turn this insidious little chunk of RNA into the world's first biological control of a virus.

"Why not vaccinate seedlings with the benign satellite-virus combination to protect them against a severe virus infection including the deadly tomato disease, which may be the satellite's natural function anyway" said Kaper to Waterworth and chemist Marie Tousignant shortly after the range of mutant types became known.

Chemists Jacobus Kaper and Marie Tousignant study pictures of gene sequences with an eye toward modifying virulent CARNA 5. (88BW0135-23)

Kaper and Tousignant, just last summer, started a 3-year series of field tests at the Beltsville (Maryland) Agricultural Research Center to see if biocontrol of the virus is possible.

In earlier laboratory tests, they had inoculated numerous plant species with cucumber mosaic virus alone or with a benign satellite-virus combination. In the latter case, the virus infection was always suppressed.

But American scientists have been slower than their counterparts in the Far East to take the benign form out of the lab and test it under field conditions. There crop losses from cucumber mosaic virus are much more severe.

Under the watchful eyes of Japanese scientists, benign CARNA 5 has performed well in the field for 2 years. When "vaccinated" plants were deliberately infected with cucumber mosaic virus, the disease was kept under control. In 1986, Kikko Foods Corporation of Japan, a large producer of tomato paste, sent one of its scientists, Haruki Sayama, to Kaper's laboratory to learn how to set up its own protection program. "So far a French group, and more recently the Japanese, have confirmed what we predicted," says Kaper.

CARNA 5 is apparently a big success in China, too, although Chinese scientists have released very little information outside the People's Republic of China about their success. Five years ago, Tien Po and his colleagues got samples of a benign form from Kaper's laboratory. With only limited field testing, they put it to work in tomato and pepper crops. "Their backs were against the wall," says Kaper, referring to their severe losses from cucumber mosaic virus. Today, thousands of acres of vaccinated plants are grown in China.

In the years since CARNA 5 was discovered, scientists have found other satellitelike agents. They have been associated with about 20 plant viruses and at least two animal viruses. And several of them have exhibited the same useful inclination to subdue their hosts.

Kaper suggests that CARNA 5 succeeds by "outsmarting" its virus host. Viruses multiply by jamming a host cell's genetic broadcasting system and commandeering the cell's assembly line to mass-produce millions of copies of itself. Somehow CARNA 5 diverts the assembly line into producing more

BOB BJORK

Healthy tomato plant at top was "vaccinated" with benign CARNA 5/virus combination, while dying tomato plant was infected with a virulent combination, thus demonstrating that benign CARNA 5 can be used as a protective agent. (88BW0296-22A)

CARNA copies than virus copies. "It outcompetes the virus," Kaper says. That's no small feat for an agent that has only about 335 nucleotides (genetic units) compared to about 8,500 nucleotides in the virus' genetic makeup. In fact, CARNA 5 has to divert the virus' replicating enzyme to multiply itself, and thus is a parasite of the virus.

A group of British scientists is exploring the possibility of transferring this protection into plant genes. They have made DNA clones of CARNA 5 and inserted them into the genes of tobacco plants. If such efforts are successful, it could be the first step toward engineering resistance against viral diseases into crop plants.

Kaper and colleagues are working toward the same goal from a somewhat different perspective. They have studied 10 of the CARNA 5 mutants and know the nucleotide sequence for each one. Kaper suspects that areas where the sequences differ represent the disease-causing regions. But to prove it, he has to alter those genes and show that that alters their pathogenicity. It won't be an easy task because CARNA 5 is RNA, and gene sequencers (laboratory equipment for dismantling genes) don't "do" RNA.

To get around this limitation in the lab, scientists resort to a complicated procedure. They first make DNA copies of the mutants, then clone lots more copies of the copies, change nucleotides in the variable areas, and convert the DNA back to RNA to see if it behaves differently in plants.

Kaper hopes this painstaking effort may begin to shed some light on how viruses interact with plant cells to cause disease. "How does a 335-nucleotide molecule cause a killing disease?" he asks. "The answer may be a simple model, but it may help us begin to understand some general concepts of the viral plant disease process, after which ways can be found to cure this disease."
—By **Judy McBride**, ARS.

Jacobus M. Kaper is at the USDA-ARS Microbiology and Plant Pathology Laboratory, Bldg. 011A, Beltsville Agricultural Research Center, Beltsville, MD 20705 (301) 344-2571. ♦

New Cornbread Adds Flavor to Sandwiches

Cornbread, a tasty but crumbly accompaniment to ham and beans since colonial days, could take on smoother, cakier texture to become a new sandwich bread, say Agricultural Research Service scientists at Peoria, Illinois.

Instead of coarse-ground cornmeal, a new specialty bread from ARS laboratory ovens contains fine-ground corn flour blended with wheat bread flour, says food technologist Kathleen A. Warner.

"Market niches for this bread are more likely in specialty bake shops, deli's, and restaurants than in supermarkets," says Warner. Perhaps someday pre-mixes may become available for home baking, she adds.

The bread's delicate corn flavor and rich golden color set it apart from conventional white and whole wheat breads, and its texture resembles that of some popular coarse-textured breads rather than conventional white breads.

BRUCE FRITZ

Food technologist Kathleen Warner prepares bread dough with 50 percent corn flour. (0487X381-16)

"It really enhances the taste of a sandwich with turkey, Swiss cheese, and alfalfa sprouts. It also makes good toast," says Warner, who has prepared a laboratory recipe for the bread, designed for professional bakers.

Gluten (wheat proteins) gives the new bread its "sandwichy" texture, says chemical engineer Leo L. Navickis. There's just enough added in the recipe to match the gluten content of typical wheat bread, he says. Also, the dough is leavened with yeast rather than baking powder as in traditional cornbread.

The new cornbread hasn't been through a formal consumer panel study. Warner rates its taste a nine on a scale of one to ten. She liked it more than most commercial white breads because of the subtle corn flavor. Plus, she says, the corn contains vitamin A, and it and the wheat provide a good balance of amino acids.

Warner used bread flour made with hard red spring wheat, but any wheat bread flour can be substituted. All-purpose flour, which many home bakers use, doesn't work; the bread won't rise properly and turns out heavy.

(continued page 13)

Self-Shielded Crops Possible

Studies on vaccinating baby alfalfa plants against disease may lead to future crops that have genes for self-vaccination, according to Agricultural Research Service scientists.

"We are trying to clear up the mysteries of how plants protect themselves from microbial pathogens," says Nichole O'Neill, plant pathologist at ARS' Beltsville, Maryland, center.

She says the research will also open new avenues for controlling plant disease without pesticides. Over 50 kinds of plant pathogens rob farmers of $6 to $8 billion worth of harvests a year from alfalfa to apples and oranges. The high value of alfalfa as a crop and its active response in induced-resistance experiments makes it the ideal laboratory "guinea pig."

"Induced resistance is not an animal-type vaccination that works with a complex immune system, but there are parallel chemical reactions in plants," says O'Neill.

She and plant pathologist C. Jacyn Baker are unraveling the molecular mechanics of induced resistance. They have already discovered that in alfalfa it is controlled by specific genes. "Since it's gene-controlled, we can try to genetically engineer crops for strong, built-in defenses," says O'Neill.

Molecules on a fungus that causes alfalfa anthracnose disease act like an antigen on an animal pathogen. Just as antigens cause the immune system to spring into action, the molecules, called elicitors, trigger an antibodylike response in plants, says O'Neill. She and Baker have isolated the antifungus response compounds in alfalfa plants that rush to an infection site.

These compounds, called phytoalexins, are not produced until infection occurs, as with antibodies in an animal. As the anthracnose fungus enters an alfalfa plant, says O'Neill, certain alfalfa genes "order phytoalexins to the scene."

Anthracnose is one of the most serious diseases of alfalfa and is most severe in the humid Southeast where more and more farmers are growing alfalfa. Fungicides are not a cost-effective control, according to James H. Elgin, formerly the agency's national program leader for research on livestock forage crops. Elgin and plant pathologist Stanley A. Ostazeski discovered induced resistance in alfalfa in 1984.

Plant pathologist Nichole O'Neill inoculates young alfalfa sprouts with a solution of harmful fungus spores. (0687X526-23)

Scientists first found induced resistance in plants other than alfalfa over 40 years ago, says Elgin, but only lately have they been able to explain some of its mechanics.

The alfalfa discovery has led O'Neill and Baker to develop the first rapid screening test to find and measure the effects of phytoalexins. The scientists use bits of alfalfa tissue growing in laboratory dishes to trace the "events of induced resistance."

"We want to know just how a plant recognizes that a disease organism is penetrating its skin," says O'Neill. "This involves isolating the elicitors from the fungus and then using DNA probes to find the proper plant genes that respond to them."

The scientists' screening tests have shown that phytoalexins can be induced from alfalfa leaves, stems, and seedlings, indicating that the natural defense works throughout the plant.—By **Stephen Berberich**, ARS.

Nichole R. O'Neill is at the USDA-ARS Germplasm Quality and Enhancement Laboratory (301) 344-3331. C. Jacyn Baker is at the USDA-ARS Microbiology and Plant Pathology Laboratory (301) 344-3617. Both are at BARC-West, Beltsville, MD 20705. ♦

Pawprint Test for Vitamin B_6 Deficiency

Making tracks through a makeshift tunnel, a young laboratory rat completes his walk for nutritionist Monica Schaeffer. The pawprints will be plotted on a computer and analyzed to detect abnormalities caused by vitamin B_6 deficiency. (0787X741-5)

A trail of pawprints left by a laboratory rat may lead researchers to a new and better way to identify people who need more vitamin B_6.

Agricultural Research Service nutrition scientist Monica C. Schaeffer says that after only 9 days, rats whose food didn't contain enough vitamin B_6 developed an abnormal gait, a step pattern that was narrower than that of their better nourished counterparts.

This pattern showed up in telltale tracks left on white paper by rats whose paws she had moistened with stamp pad ink. The tests revealed otherwise undetectable problems the rats had in moving their hind legs.

If this observation holds true for the human volunteers that Schaeffer hopes to test, then the way people walk, or gait analysis, may prove to be a fast, painless way to find who is or isn't getting enough of this essential nutrient.

A new test for vitamin B_6 is needed, Schaeffer says, because of the number of people in the United States who are thought to be short of this vitamin and because of problems with existing tests.

Today's accepted tests for vitamin B_6 are biochemical, meaning that they analyze chemicals from the body, such as those in blood or urine. Each test has limits—one, a tryptophan loading test, for example, makes some people sleepy and nauseous. Perhaps even worse, the test requires collecting urine for 24 hours.

Half the people in the United States today may be getting less than 70 percent of the Recommended Dietary Allowance of 1.8-2.2 mg daily. The most likely candidates for this marginal deficiency: females over the age of 15, especially those who go on fad diets to lose weight, and the elderly of both sexes.

What Schaeffer envisions as a supplement or complement to these biochemical tests is a "functional" test based on an observation of some normal activity that's linked to vitamin B_6.

This functional test should be reliable for detecting marginal vitamin B_6 deficiency—long before the more obvious symptoms of a severe deficiency show up," says Schaeffer. Gait analysis, occasionally used to test the effects of drugs or toxins, may work as a functional test for this vitamin because of the key role the nutrient plays in keeping the nervous system healthy.

"We already know that control of such motor actions as walking and running depends on normal nerve function," says Schaeffer. "And nerves can't work properly if there's a B_6 deficiency. Nerves have sheaths that act like insulators, allowing electrical impulses or messages to be carried down the length of nerve. In B_6 deficiency, these sheaths degenerate, so the pulses can't be carried normally. We're not sure, but this might be what's going on inside the B_6-deficient rat with the abnormal gait."

The human body needs vitamin B_6, not only to keep the nervous system running smoothly, but for many other vital chemical reactions, such as the conversion of an amino acid, tryptophan, into the vitamin niacin, or for proper functioning of many enzymes.—By **Marcia Wood,** ARS.

Monica C. Schaeffer is at the USDA-ARS Western Human Nutrition Research Center, P.O. Box 29997, San Francisco, CA 94129 (415) 556-5655. ♦

New Cornbread (continued from p. 11)

The new bread came out of research Navickis conducted into the physical properties of doughs containing corn flour at the request of the American Corn Millers Federation.

As baking companies consider market development and conduct their own taste tests, they might want to ask corn millers to provide specific kinds of corn flour. Jack Swarthout, director of research for the American Corn Millers Federation, says the horny endosperm type of corn used to make beer and grits wouldn't make a flour with much flavor. A richer flavor would come from other types, especially from the germ portion of the kernel or fractions that are finely ground after coarser milled fractions have been diverted for other uses.

Edward B. Bagley, who heads research on food physical chemistry at the Peoria center, says "The Federation obviously wants to expand their market for corn in foods, but we also think this work might be pertinent to industrial uses of corn flour and other surplus agricultural products."

For example, he says, studying interactions between protein and starch may lead to a modified corn flour that could be used in paper and fabric manufacturing without imparting undesirable textures to the finished products.

"We try to keep alert to ways of adding value to agricultural commodities," Bagley says.—By **Ben Hardin,** ARS.

Kathleen A. Warner, Leo L. Navickis, and Edward B. Bagley are at the USDA-ARS Northern Regional Research Center, 1815 North University Street, Peoria, IL 61604 (309) 685-4011.

Carbonated Milk: Soft Drink That's Not Junk Food

Countless things have happened to milk since the first cows arrived in the United States at Jamestown in 1611. It has been bottled, pasteurized, homogenized, fortified with Vitamin D, skimmed of its fat, powdered, flavored, and put in plastic containers, to name a few.

Now Agricultural Research Service scientists have taken perhaps the ultimate step in bringing milk into the 20th century and beyond. They've carbonated it.

Researchers at ARS' Southern Regional Research Center in New Orleans were looking for new ways to use surplus powdered milk when they came up with what could be called soda milk.

Actually, they've made two types of this carbonated brew—one with artificial strawberry flavoring and the other mixed with filtered apricot juice, according to food technologist Ranjit S. Kadan.

Soda milk is made by bubbling carbon dioxide gas through a mixture of water, powdered nonfat dry milk, flavoring or apricot juice, and other ingredients. The mixture is kept under pressure and bottled right away so the carbonation doesn't escape.

"It's only a crude laboratory mixture, but it tastes great," Kadan says. "You get that tingling, refreshing sensation of carbonation that you get in soft drinks, and you're also getting calcium, protein, and Vitamin C from the milk and juice."

In tests last year, Kadan says, the strawberry-flavored milk stayed fresh up to 6 months under refrigeration; the juice mixture lasted 2 to 3 months.

"We've shown that you can make a carbonated drink in which the powdered milk stays suspended and doesn't separate in the mixture," Kadan says. "Commercial companies would have to refine the process and add other flavors before you'll find it in the supermarket."

Kadan used strawberry flavoring he bought in a local supermarket. The apricot juice was filtered using processing methods adapted by Charles C. Huxsoll and colleagues at the ARS Western Regional Research Center in Albany, California.

Hopefully, Kadan says, carbonated milk beverages will spur consumption of milk. Between 1975 and 1985, per capita milk consumption in the United States dropped 12 percent, according to the Milk Industry Foundation's 1987 Fact Book. During the same time, per capita consumption of soft drinks increased 68 percent.

This means that milk, a valuable source of calcium, is being underutilized. A cup of 2-percent milk contains 297 mg of calcium—more than one-third of the recommended 800 mg per day for adults and young children. Most soda contains no calcium. "Carbonated milk would be a big help for children, who need calcium as their bones develop," Kadan says.

Aside from its nutritional advantages, carbonated milk would also help spur commercial use of powdered, or nonfat dry, milk. "If our new drink captured 3 to 5 percent of the carbonated drink market, it could wipe out the powdered milk surplus," says Kadan.

Powdered milk use dropped by a little over 50 percent between 1975 and 1985. In 1987, the milk surplus was estimated

Diet Studies To Rely on Home Computers

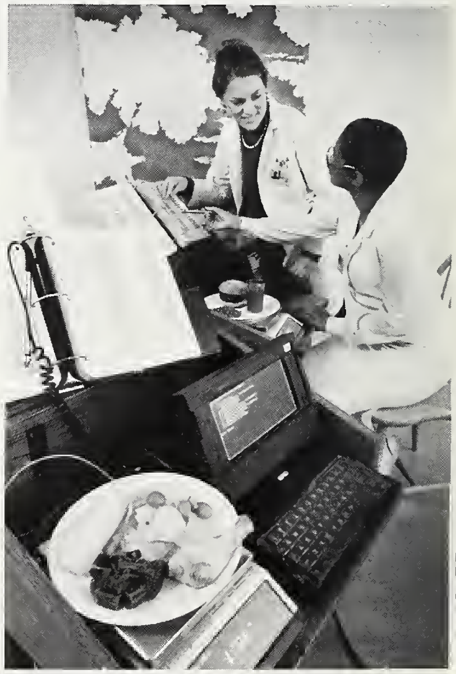
Families in future diet studies may electronically weigh and record what they eat at home and send the data through a computer to a nutrition laboratory for analysis, according to an Agricultural Research Service nutrition scientist.

"If we can gather more accurate data, as we expect, then we should have a clearer picture of whether people are getting the nutrients they need to stay healthy and fit," says Mary J. Kretsch, a research nutrition scientist for USDA's Agricultural Research Service.

"Thousands of pieces of data are taken in a diet study. The new electronic system will help volunteers to record data immediately and send it over the telephone to researchers at the end of the day. It's a massive job for nutritionists to analyze and tabulate such data, but computerization will speed up and simplify our job."

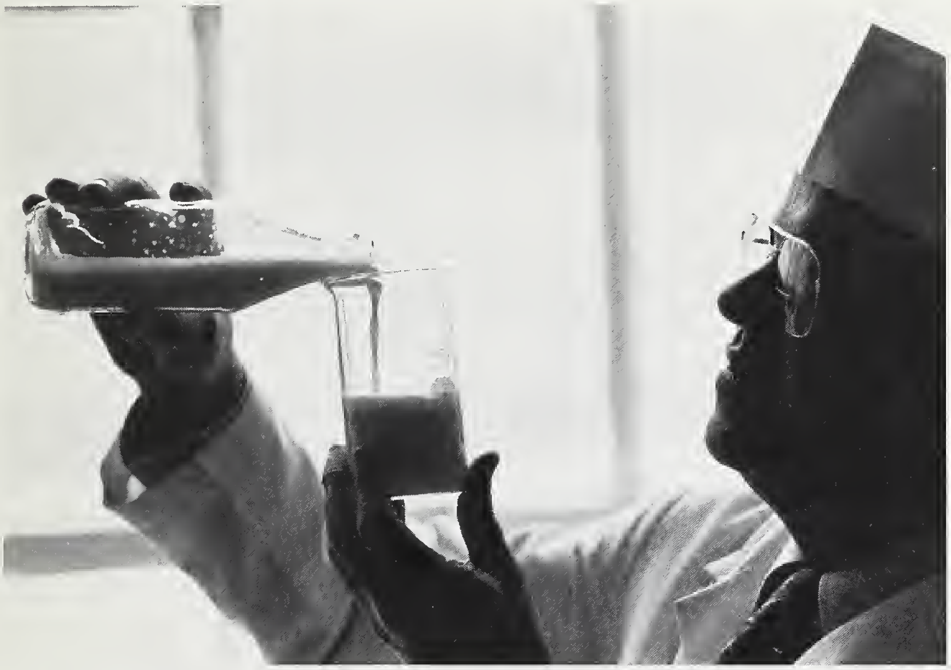
Kretsch is working to refine the system and expects it to be ready for regular studies in 1989. She says 21 volunteers in two pilot tests each learned the system. That involved using a portable computer linked to an electronic scale to automatically record the precise weight of each food on the computer. It also required using a computer-linked barcode reader similar to ones at supermarket checkout counters to log the food's identity.

She calls the system "one of the major advances in determining American dietary patterns in more than 40 years.



TIM McCABE

Nutrition scientist Mary Kretsch (left) explains how to operate the computerized food scale to a volunteer participating in the dietary study. (0787X738-23)



JACK DYKINGA

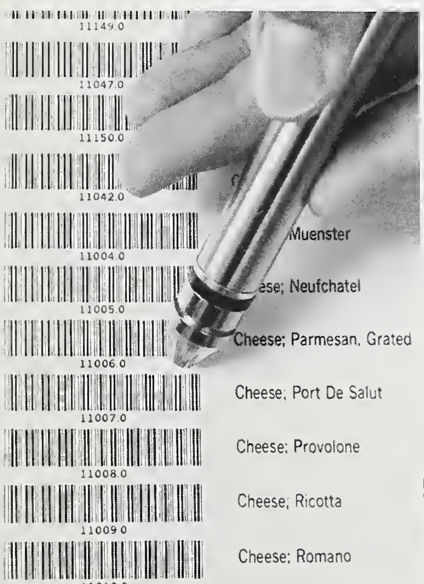
Ranjit Kadan pours out a bottle of carbonated milk to check its consistency. (0387X132-36)

at about 6.5 billion pounds, of which about 550 million pounds was powdered milk, according to USDA estimates. The government paid about $1 billion last year to buy the surplus milk in the form of powdered milk, butter, and American cheese. Another product Kadan has developed is a custardlike dessert made with nonfat dry milk, rice flour, and sugar mixed with gums and a little vegetable oil. The gums provide the egg custardlike texture to the new dessert, giving it a consistency similar to rice pudding and to a French dessert called flan.

Kadan says his dessert doesn't have cholesterol because it has no eggs as flan does.

Kadan and USDA-ARS have received a patent on the custard, and, he says, if it's developed commercially it probably would be sold as a powder in packets like instant oatmeal. It would be prepared by adding hot water, stirring, and cooling for about an hour. Or processors could mix it and sell it in containers, as yogurt is sold.—By Sean **Adams**, ARS.

Ranjit S. Kadan is at the USDA-ARS Southern Regional Research Center, 1100 Robert E. Lee Blvd., P.O. Box 19687, New Orleans, LA 70179 (504) 286-4332. ♦



TIM McCABE

A key component of the computerized food scale is a bar code reader that records the identity of each food. (0787X739-32)

This is because recent improvements in portable computers now give us radically different ways to streamline and upgrade the way we collect data."

She says the system might reduce chances of volunteers failing to record snacks and other foods they eat. They may forget to write in food diaries or cannot remember in face-to-face interviews what they have eaten, she says.

At times in earlier studies, some data on meals would be missing. Volunteers would report they ate a frozen dinner, for example, but not the different foods in it.

Now, volunteers will use special barcodes from a new barcode catalog Kretsch and colleagues developed to record the contents of the packaged dinner. The catalog includes codes for some of the most popular frozen foods as well as codes for fresh fruits and vegetables and hundreds of other foods.

The diet-monitoring electronics will make it cheaper and faster to detect unhealthy diet trends, such as overuse of salt or overeating of high-fat foods.

"Nothing on the market now is comparable for detailed studies," she says. "We will be able to study the nutritional patterns of a family in depth for anywhere from several weeks up to a year."

A problem the system may not solve, Kretsch says, is one always arising in diet surveys—people who give wrong information because they are sensitive about what or how much they ate.

Nevertheless, she says, the new system will be easy to use, even for someone who hasn't worked with a computer.—By **Marcia Wood,** ARS.

Mary J. Kretsch is at the USDA-ARS Western Human Nutrition Research Center, P.O. Box 29997, San Francisco, CA 94129 (415) 556-6231. ♦

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PATENTS

Polytherm: Time To Take a Technology Transfer

Readers familiar with *Patents* know this regular feature of *Agricultural Research* serves to publicize the more than 1,200 patents and patent applications held by the U.S. Department of Agriculture. Mention in this column is of course no guarantee of fame or commercial success for an invention or its inventor.

Still, we're pleased to offer our readers an occasional first glimpse of a commercial rising star. Such a brush with destiny seemed to occur in our April 1987 issue, when we heralded the patent application for a textile treatment called Polytherm.

Out of Whole Cloth

"Clothing of the future may actually sense when the air temperature is dropping," reporter Hank Becker noted, "and release heat stored in the fabric to keep the wearer comfortable. The heat-transfer process would be reversible so that in hot weather the clothing would feel cool to the skin."

The article described how Polytherm worked, by binding chemicals called polyethylene glycols to textiles such as cotton, cotton/polyester blends, and worsted wool.

Inventors Tyrone L. Vigo, a chemist for ARS in New Orleans, Louisiana, and his colleague, Joseph S. Bruno, began experimenting on the temperature-adaptable fabric in 1981. They selected the name Polytherm for their new treatment because of its ability to adapt to many temperatures.

Although Vigo noted that there was still a lot to be learned about the fabric treatment, his work has already inspired interest among textile manufacturers and users of specialty fabrics.

On to the Marketplace

Here was a product that seemed to burgeon with potential uses—from building insulation and draperies to gloves, shirts, work clothes, socks, towels, and sheets. But how might an agency whose mission is restricted to agricultural research get into the marketing business and successfully move the benefits of its research to the public?

By coincidence, President Reagan had recently signed an executive order intended to boost the transfer of technology from government to industry. The legislation gave new authority to the federal government to enter into cooperative research agreements with companies.

The presidential action couldn't have come at a better time for Polytherm or for the scientists and administrators who had become caught up in a wave of Polytherm enthusiasm. In June 1987, they offered private industry its first opportunity to develop commercial uses for the chemically treated fabrics.

The agency, in cooperation with the National Technical Information Service, mailed letters and put together a "technology opportunity package," touting the chemically treated fabric. This multimedia promotional package containing a videotape, fabric samples, and technical papers was available to industry for $325. Over 50 packages were sold to companies throughout the United States. The effort worked. Polytherm soon captured the attention of the media, and inquiries began to pour in from businesses at home and abroad.

Commenting on the concerted marketing effort for Polytherm, Agricultural Research Service Administrator Terry B. Kinney, Jr., described it as a prototype for increasing the flow of research from laboratory to marketplace.

Although several potential licensees have been identified for Polytherm, the marketing effort continues. Richard M. Parry, an assistant to Kinney, points out, "It is fortunate that ARS can be flexible in making arrangements with industry to develop Polytherm."

This month, top ARS scientists and administrators will convene in New Orleans to discuss technology transfer. High on the agenda: mapping out a strategy for the promising fabric finish. For technical information on Polytherm, contact Tyrone L. Vigo and Joseph S. Bruno at the USDA-ARS Textile Chemistry Unit, Southern Regional Research Center, 1100 Robert E. Lee Blvd., New Orleans, LA 70179 (504) 286-4487. *Patent Application Serial No. 06/818,567, "Temperature Adaptable Textile Fibers and Method of Preparing Same."*

For information on licensing patents listed on this page or to receive a catalog of USDA patents, contact Ann Whitehead, coordinator, National Patent Program, USDA-ARS, Room 401, Bldg. 005, Beltsville, MD 20705.